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BRNO UNIVERSITY OF TECHNOLOGY
VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
FAKULTA ELEKTROTECHNIKY
A KOMUNIKAČNÍCH TECHNOLOGIÍ

DEPARTMENT OF FOREIGN LANGUAGES
ÚSTAV JAZYKŮ

FROM INDUSTRIAL ROBOTS TO ANDROIDS
OD PRŮMYSLOVÝCH ROBOTŮ K ANDROIDŮM

BACHELOR'S THESIS
BAKALÁŘSKÁ PRÁCE

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VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
FAKULTA ELEKTROTECHNIKY A KOMUNIKAČNÍCH TECHNOLOGIÍ

Bakalářská práce

bakalářský studijní obor **Angličtina v elektrotechnice a informatice**

Ústav jazyků

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Od průmyslových robotů k androidům

POKYNY PRO VYPRACOVÁNÍ:

Popište vývoj inteligentních robotických systémů a odvoďte klíčové aspekty designu androidních robotů. Zvažte další možnosti kontroly myšlení, vědomí a emocí androidních robotů.

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1. Breazeal Cynthia L.: Designing Sociable Robots. ISBN 0-262-52431-7

2. Arkin Ronald C.: Behaviour-based robotics. ISBN 0-262-01165-4

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ABSTRAKT

Tato bakalářská práce je zaměřena na téma robotiky. V teoretické části se stručně zabývá pojmem robot a popisuje historii robotiky, od nejprimitivnějších vynálezů až po dnešní androidy. Věnuje se zejména těm nejvýznamnějším milníkům v průběhu historie. Dále se zabývá problematikou společenských robotů. Zaměřuje se na to, co dělá robota společenským a řeší nejrůznější designové a etické problémy spojené s konstrukcí takového druhu robota. Poslední část se zabývá legálními a etickými problémy v robotice podle Evropského parlamentu. V praktické části jsou prezentovány výsledky dotazníkového průzkumu.

KLÍČOVÁ SLOVA

Robot, robotika, historie robotiky, společenský robot, problémy společenských robotů

ABSTRACT

This bachelor's thesis is focused on the theme of robotics. In the theoretical part, it briefly introduces the term robot and then it describes history of robotics from the most primitive inventions to today's androids. It mainly focuses on the most significant milestones throughout the history. The next part aids at the problematics of sociable robots. It describes the aspects of sociable robots and deals with various design and ethical issues associated with the construction of a sociable robot. The last part deals with legal and ethical problems according to the European Parliament. In the practical part, results of the questionnaire survey are presented.

KEYWORDS

Robot, robotics, history of robotics, sociable robot, issues of sociable robots

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PROHLÁŠENÍ

Prohlašuji, že svou bakalářskou práci na téma Od průmyslových robotů k androidům jsem vypracoval samostatně pod vedením vedoucího semestrální práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.

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V Brně dne ....

(podpis autora)

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I would like to sincerely thank my thesis supervisor Mgr. Bc. Dagmar Šťastná for her invaluable advice while writing my bachelor thesis, for her patience and kind support, which helped me in creating it.

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Introduction

Robots have always seemed really fascinating to me. They represent a huge part of our modern culture, they are showing up all the time in sci-fi movies and novels and with advancing technology, robots are becoming more common than ever in our society and everyday lives. Some people might be afraid of this technological progress, because of all the catastrophic films, where self-aware robots take over the world, become our overlords and make us work for their pleasure or annihilate us. However, there are also people like myself, who are really intrigued by the idea of having a peaceful, useful and resourceful robot at home, for example C-3PO and R2-D2 from *Star Wars*, Johnny Five from *Short Circuit* or even Wall-E from *Wall-E*.

The robot revolution is in fact already happening and it has been happening for years. Just one simple look at the manufacturing and automobile sectors is enough to see that robots completely replaced humans. They cut and mould parts, inspect and assemble different pieces. Robots help shoot movies, they assist in docking spacecraft at the International Space Station or they can help you doing vacuuming the floor at home. They work at places that are way too dangerous or onerous. The possibilities are endless and we can just eagerly wait what the future will bring.

In the theoretical part of my thesis I will focus on the history of robotics, what the robot exactly is and what main advancements throughout the past up to today's androids were achieved. Next, I will define what a sociable robot is and what are the main aspects for designing such a robot. I will outline some design and ethical issues. The last part deals with legal and ethical issues according to the European Parliament.

In the practical part, I will present results of a questionnaire survey, which I have conducted. The goal of this questionnaire was to acquire information about people's stance on sociable autonomous robots in society.

THEORETICAL PART

1 History of robotics

This chapter deals with the history of robotics. First, however, I would like to explain what exactly a robot is supposed to be.

1.1 What is a robot?

It is quite tricky to define what a robot is, there is really no definition for it, but technically speaking a robot is just a machine designed to accomplish a task. There are four essential characteristics that a robot must have; it must be able to sense, move, think and be powered. It is sort of similar to a human. [18]

First of all, a robot must be able to sense its surroundings with sensors (light, touch, pressure, chemicals, hearing, taste). Then, it has to be able to move, either only partially (arm) or the whole robot moves (wheels, legs etc.). Another important part is its intelligence, which is the programming; in other words, what it is supposed to do. And the last essential thing is that it needs to be powered somehow – batteries, electricity, solar energy or any other source of power. [18]

These are the basics of robot anatomy, but there are so many kinds of robots and therefore these characteristics can vary considerably.

1.2 History of robotics (82 B.C. – 1921)

Some people might think that robots are a recent invention, but the idea of robots has been around for thousands of years, dating back to ancient times. Apart from the mythological robot-like devices, there are a lot of accounts in early literature about automata (automaton = a mechanism that is relatively self-operating; especially robot) [12] in ancient Greece and China. [24]

1.2.1 The Antikythera Mechanism

One of the oldest surviving automata is called *The Antikythera Mechanism*. It was discovered in a shipwreck off Antikythera island in 1900 by a Greek sponge diver. It was most likely built in 82 B.C and it is considered to be the first analogue computer, which allowed the ancient Greeks to calculate the position of the sun, the moon and then the known five planets (Mercury, Venus, Mars, Jupiter and Saturn). Nothing as sophisticated and complex as this was not discovered for the next thousand years. [26]

Figure 1 - 82 remaining fragments of The Antikythera mechanism [26]

1.2.2 Ismail al-Jazari

The world's oldest programmable automaton is claimed to be al-Jazari's drinking boat – it was constructed in 1206. This machine was a boat with four musicians – 2 drummers, a harpist and a flautist. It floated on a lake and entertained guests at parties. The core of this device is a rotating cylindrical beam with pegs bumping into little levers that operated the drums. It was supposed to demonstrate that by using the pegs, the drummer can play different rhythms. [7]

1.2.3 Leonardo da Vinci

One of the greatest inventors of the mankind Leonardo da Vinci designed several automata, although it is not clear how they worked. There are many interpretations of these inventions, because the details are not fully defined in his manuscripts. One of the most famous is a humanoid automaton called the *Mechanical knight*. This knight was demonstrated in 1495 in Milano. It was a knight in German-Italian armour of the 15th century and it could make some human-like movements – sit up, wave, move neck, open a jaw. It was probably designed for whole-arm grasping, because the joins moved in unison. The arms were powered by an analogue controller in its chest and the bottom was powered by a crank connected to a cable. [13]

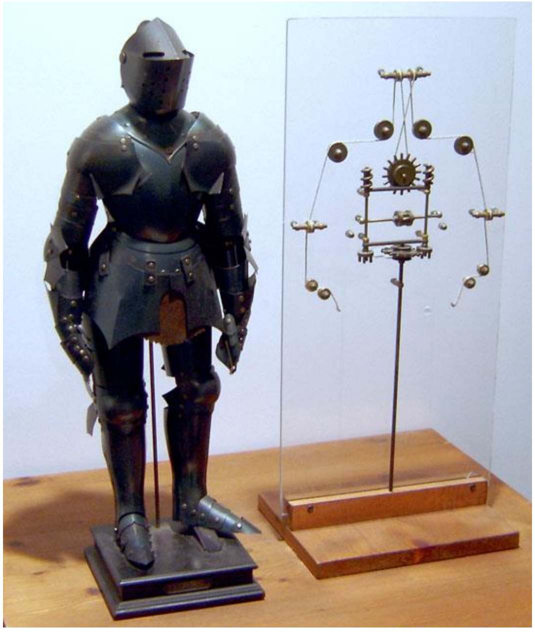


Figure 2 - Leonardo's Mechanical Knight [13]

1.2.4 Jacques de Vaucanson

A genius French engineer Jacques de Vaucanson is considered to be the first person to create the first *true* robot. In 1737, he finished *The Flute Player*, which was a 1.78 meters tall figure of a shepherd playing the transverse flute. It emitted wind out of its mouth and played an actual flute with its moving fingers. In 1738, Vaucanson presented two more automatons, *The Tambourine Player* and his masterpiece *The Digesting Duck*. [14]

The Digesting Duck was made of copper and it had more than 400 moving parts. It was capable of imitating a real duck. It could quack, flap its wings, drink water, digest grain and defecate. It was a huge success in France, where people would stand in lines to see this duck. These three automatons were revolutionary, because of their life-like sophistication. The musicians were destroyed in the 19th century and the duck burn in a museum in Krakow in 1889. [14]

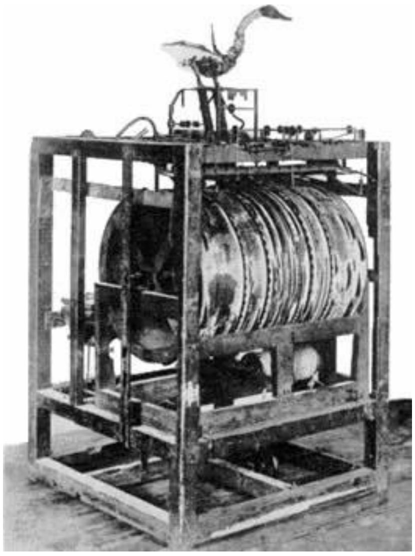


Figure 3 - The Digesting Duck [14]

1.2.5 Hisashige Tanaka

Japanese craftsman, also known as “Japan’s Edison” Hisashige Tanaka, who lived from 1799 to 1881, designed the most complex mechanical toys. These toys could serve tea, fire arrows and write. [28]

1.3 History of robotics (1921 – 2006)

The word robot first appeared in Karel Čapek’s play *R.U.R.* in 1921. However, his brother Josef Čapek is thought to be the originator of the word. It comes from the Czech word “robota” which means forced labour. [24]

1.3.1 Gakutensoku

In 1928, the biologist Makoto Nishimura designed and constructed Japan’s first robot – *Gakutensoku*. It was unveiled to the public at the Kyoto Grand Exposition in commemoration of the Imperial Coronation. Its face combines the characteristics of people all around the world to symbolize equality. Rubber tubes and an air pressure mechanism allow this robot to move its eyes, eyelids, cheeks, mouth, neck, and chest. The air is pushed around by a rotating cylinder located at the centre of the robot. [19]

Figure 4 - Gakutensoku with its creator [19]

1.3.2 Elektro and Sparko the dog

During 1937 and 1938, a robot named *Elektro* was built by Westinghouse. It was introduced to the public at the 1939 New York World's Fair. It was constructed from aluminium on a steel frame, was seven feet tall and weighed 120 kilograms. It was also capable of uttering circa 700 words and responding to commands. Four rubber rollers were under each foot which enabled it to walk. Moreover, it was capable of rotating its arms, fingers and head and could even smoke. In total, it was operated by 11 motors – one powered the rubber rollers, one for smoking and the other nine ones operated its fingers, arms and turntable for talking.

It returned to the New York World's Fair again in 1940 together with *Sparko the dog*, which was a robot that imitated a dog and could bark.

Figure 5 - Elektro and Sparko the dog [15]

1.3.3 The Three Laws of Robotics

Isaac Asimov is thought to be the first person to use the term robotics to describe the technology of robots. It came about in 1941. He also proposed the Three Laws of Robotics in his short story *Runaround* in 1942, which are as follows:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm
2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

A fourth or a "zeroth law" was later added:

4. A robot may not harm humanity, or, by inaction, allow humanity to come to harm.

Later, in 1950 his short stories about robots were compiled and published as a single volume *I, Robot*. [24]

1.3.4 The Turing Test

In 1951, Alan Turing proposed a test called *The Imitation Game*, which would determine whether a machine is intelligent or not. First, there was no machine at all, there were three people - a man, a woman and a third person or a "judge". Judge's job was to decide which of the two people is the man. The woman's job was to deceive the judge for him to identify her as a man.

Now, Turing proposed that instead of a man and a woman there was a human of whichever gender and a computer. The judge's job was to decide which one is a human and which one is a computer. According to Turing, if the judge is accurate less than 50% of the time then the computer must be a passable simulation of a human, hence, intelligent.

However, there is a lot of controversy surrounding this test even today. Some people say that it is a poor test of intelligence and others that it is a valid scientific criterion. [9]

1.3.5 Unimate

From this point on, the development in robotics has started to escalate quite quickly.

The *Unimate* was the first industrial robot designed by an American inventor George Devol. The robot joined the production line at the General Motors plant in 1961. It was basically a giant robot arm, weighting nearly a metric ton. It performed commands, stored on a huge magnetic drum, doing tasks, which were unpleasant and dangerous for people (lifting and stacking hot pieces of die-cast metal). This machine spawned a robotic arm revolution with other car companies following General Motors with their own robotic arms. The first generation of arms were not particularly flexible and they were also quite difficult to program. [8] [24]

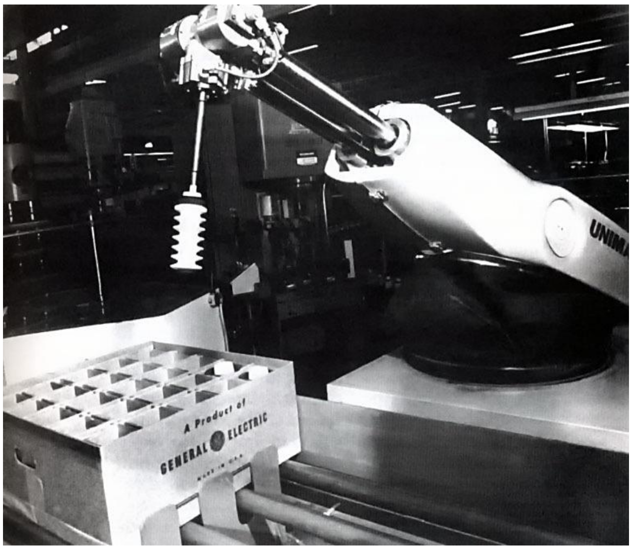


Figure 6 - UNIMATE robotic arm in an industrial setting [8]

1.3.6 Stanford University

John McCarthy was a computer scientist, Stanford professor, and is known as the father of artificial intelligence, or AI for short. He coined the term in 1955. AI is vastly important in the development of human-like robots. In 1958, he also created the *Lisp* computer language, which is a standard artificial intelligence programming language and it continues to be used even today. In 1959, he co-founded together with Marvin Minsky the Artificial Intelligence Laboratory at Massachusetts Institute of Technology. However, in 1963, when their views began to differ, McCarthy came back to Stanford and founded Stanford's AI Laboratory (SAIL). [10] [24]

In 1966, Stanford Research Institute (known as SRI Technology today) created *Shakey the robot*, which was the first mobile robot with the ability to perceive and reason about its surroundings. This robot influenced robotics and AI research with its ability to perform tasks that required planning, rearranging of simple objects or route finding. [25]

In 1969, a Mechanical Engineering student, working at SAIL, Victor Scheinman, created the *Stanford Arm*, which was exclusively designed for a computer control. This arm's design is influencing the robotic arms design constructed even today. [24]

Stanford University also produced the *Stanford Cart*, which was designed to be a line follower and could be controlled via radio link from a computer. [24]

Another big step was an introduction of the first electric industrial robot controlled by a microcomputer in 1974 called *IRB-6*. Developed by a Swedish engineering firm ABB, this robotic arm had 16kb of RAM and could display four digits using its LEDs. It performed adverse tasks like polishing steel tubes.

Figure 7 - Shakey the robot [25]

1.3.7 Takeo Kanade and Genghis

Takeo Kanade built the first direct drive arm. The motors were installed directly into the joins and that made them much more fast and accurate than previous robot arms. This design influenced direct drive arms used in industry today. [24]

A hexapodal robot named *Genghis* was revealed at MIT in 1989. It used 4 microprocessors, 22 sensors and 12 servo motors. [24]

Figure 8 – Genghis [30]

1.3.8 NASA rovers (National Aeronautics and Space Administration)

The designs of these rovers are very similar. They are basically multiple-wheeled carts with built in cameras to monitor the surface of Mars and with some obstacle avoidance program to avoid getting stuck and thus ending the mission abruptly.

The Mars rover *Sojourner* was part of NASA's Mars Pathfinder mission and landed on Mars on July 4, 1997 and continued to explore Mars for about three months. It was equipped with a front and rear camera and an obstacle avoidance program. [23]

Another rover, which NASA deployed on Mars was *Spirit* rover. This one together with the *Opportunity* rover is part of ongoing Mars Exploration Rover Mission. *Spirit* was active on Mars from 2004 to 2010, when the communication with the Earth ceases to continue. The *Opportunity* rover landed on Mars on January 25, 2004 and it continues to operate as of 2017. [21]

The most recent rover, which was deployed on Mars, is a *Curiosity* rover, which is part of Mars Science Laboratory mission. It landed on Mars on August 6, 2012 and continues to operate until today. NASA is planning to deploy a similar designed *Super Curiosity* rover in 2020, which will supposedly even broadcast audio from the Red Planet. [22]

1.3.9 Cornell University

At Cornell University in 2006, researchers built a robot that can adapt to injuries called *Starfish*. It is a simple four-legged machine, but they say the algorithm could be used to build much more complex robots in the future, which would be able to deal with uncertain and possibly dangerous situations like space exploration. [11] [24]

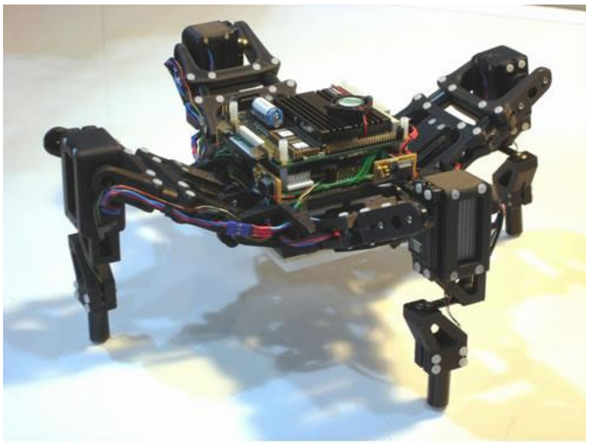


Figure 9 – Starfish [11]

1.4 Humanoid robots

Some of the humanoid robots have already been mentioned in the chapters above like da Vinci's automata, Vaucanson's inventions, *Gakutensoku* or *Elektro*. These had the properties of a human body (arms, legs, head), but were not very clever. This chapter will focus on a few humanoid robots, which not only have anthropomorphic (described or thought of as having a human form or human attributes [29]) appearance, but are also quite smart.

1.4.1 WABOT

In 1970, four laboratories in the School of Science and Engineering of Waseda University started the WABOT project. *WABOT-1* was the first anthropomorphic robot in the world and was defined as a versatile robot. It had a fully functional limb-control system, it was able to communicate in Japanese and with its vision system it could also measure distances and direct itself to an object and was able to grab it and transport it. *WABOT-1* was estimated to have a mental faculty of a one-and-a-half-year-old child. [16]

The first milestone in the development of a personal robot was the *WABOT-2* project launched in 1980. This one was defined as a specialist robot, because it was set up to play a keyboard instrument, which was considered to be an intelligent task requiring human like intelligence. It was capable of accompanying a person when the person was singing, conversing with people, reading a musical score and playing tunes according to it. [16]

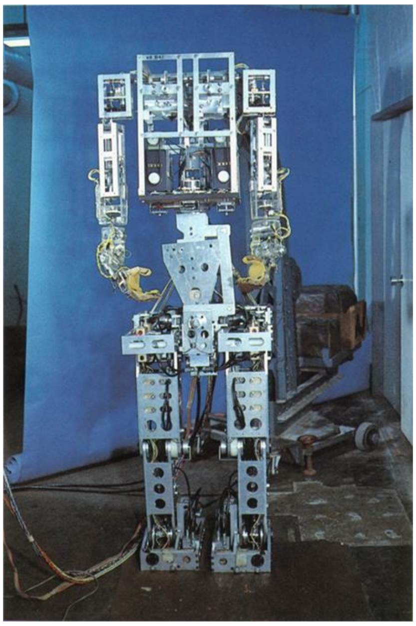


Figure 11 - WABOT 1 [16]

Figure 10 - WABOT 2 [16]

1.4.2 ASIMO

In 2000, Honda's Advanced Step in Innovative Mobility humanoid robot called *ASIMO* was introduced. Its physiology is developed to mimic human physiology, it can walk and even run up to 9 km/h. The most innovative feature of this robot is its advance intelligence, the robot can think and act on its own without human intervention. *ASIMO* has sensors that can replicate 5 human senses. It can recognize human faces, converse using artificial intelligence and understand multiple utterances said at once. Its head contains 8 microphones that allow the robot to listen and engage in a conversation. *ASIMO* was designed to help people and make life easier. An updated version with new behaviours and capabilities was introduced in 2005 and then in 2011. [17] [24]

Figure 12 – ASIMO [24]

1.4.3 Hanson Robotics

Hanson Robotics captivated the world with their remarkable human-like robots. They created robots, which could really be mistaken for a real person, because of their incredible expressiveness, aesthetics and interactivity. Their robots have personalities and can interact with people in unique ways. The most famous ones are *Albert Einstein HUBO*, a conversational character robot *Jules*, android of renowned sci-fi writer *Philip K. Dick* or their latest creation the most beautiful and expressive robot *Sophia*. [27]

Figure 14 – Sofia [31]

Figure 13 – Jules [32]

1.4 Summary

This chapter outlined some of the most important milestones in the history of robotics. It all began in 82 B.C. when the ancient Greeks developed the most sophisticated and complex device at the time called *The Antikythera Mechanism*, which is considered to be the first analogue computer. In 1206, Ismail al-Jazari constructed a boat with four musicians, which is claimed to be the world's oldest programmable automaton. Leonardo da Vinci also designed several automata. One of his most famous is a humanoid automaton *The Mechanical Knight*, which was demonstrated in 1495 in Milano. In 1738, Jacques de Vaucanson, who is considered the first person to create the first *true* robot, presented his masterpiece *The Digesting Duck*. This automaton had more than 400 moving parts and was able to imitate a real duck. The first robot in Japan was called *Gakutensoku* and it was designed and constructed in 1928 by the biologist Makoto Nishimura. A seven feet tall aluminium humanoid made an appearance at the 1939 New York World's Fair. This robot named *Elektro* could utter circa 700 words and could respond to commands. In 1942, Isaac Asimov proposed the Three Laws of Robotics in his short story *Runaround*. The first robotic arm joined the production line at General Motors in 1961; it was called *Unimate* and it spawned a robotic arm revolution. At Stanford University, a computer scientist John McCarthy pushed artificial intelligence forward. In 1958, he created artificial intelligence programming language *Lisp*, which continues to be used even today and it is really important in the development of human-like robots. NASA is also part of this robotic revolution with its Mars rover *Sojourner*, which operated on Mars in 1997, the Mars rovers *Spirit* and *Opportunity*, which landed on Mars in 2004. *Opportunity* continues to operate as of 2017. The latest Mars rover *Curiosity* landed on Mars in 2012 and operates until today. Even some intelligent humanoid robots were invented. In 1970 and 1980 *WABOT-1* and *WABOT-2*, respectively, were introduced. Then in 2000, Honda introduced a humanoid robot *ASIMO*. This robot could think and act on its own, converse and understand multiple utterances said at once. It was updated since then. And last but not least, scientists from Hanson Robotics invented some remarkable human-like robots, which could be mistaken for a real person.

2. A sociable robot

This chapter defines what a sociable robot is, what the main aspects when designing such a robot are and deals with some design and ethical issues of sociable robots.

There are a lot of various applications for sociable robots and the level of social intelligence should reflect the requirements of the specific application domain. The bullet points below show increasing social skills requirements in different occupations. For example, you can see that a remotely controlled space robot does not need to be particularly social unless it somehow communicates with a human or some other robot. On the other hand, a robot companion at home or a care taker for sick and elderly people must have a wide range of social skills. Robot companions must be able to provide human-like interactions with people, otherwise they would fail in their role as a social robot companion. (Dautenhahn, 2007: 679-704)

Spectrum of requirements for robot social skills in ascending order (Dautenhahn, 2007: 679-704)

- Remote controlled/spatially – temporally separated (surveillance, space robots)
- Agriculture, cleaning, firefighting
- Tour guides, office/hotel assistants
- Entertainment
- Robots in nursing care, rehabilitation, therapy, e.g. autism therapy
- Robot companion at home

2.1 What is a sociable robot?

Couple of robots have already been mentioned in the previous chapters, but I do not think that a *truly* socially intelligent robot has been invented just yet. A sociable robot should be able to express emotions and be able to relate to other people's or robots' feelings. It should be capable of communicating with high-level dialogue, it should be able to befriend us and be able to maintain that relationship, learn and develop social competencies, have some endearing personality and character. Interacting with a sociable robot should be like interacting with another person. Basically, a robot with a human-like intelligence is a sociable robot. (Fong *et. al.,* 2003; 145)

A lot of various definitions of social robots have been used in the literature. Breazeal (2003; 169) divided social robots into 4 subclasses according to their ability to approach the human social environment and human style face-to-face interaction.

Socially evocative – this subclass encourages people only to anthropomorphize the technology and nothing more. It exploits the owner's feelings, when people interact with their creations and take care of them. It is most common in toys – pet-like robots.

Socially communicative – this subclass of robots uses human-like social cues and communication patterns to make the interactions with people more natural and familiar. Most commonly used communicative robots are museum tour guides, where information is conveyed using speech and sometimes also reflexive facial expressions. However, there can also be more complicated ones, where people use a robot avatar to communicate with others. This type requires a sufficient social intelligence to convey a message complemented with gaze, gestures, facial expressions etc.

Socially responsive – socially responsive robots benefit from interacting with people. They can learn through human demonstration. They are socially passive, but they respond to individual's attempts to interact with them. These interactions shape the robot's behaviour.

Sociable – these robots are socially active, they proactively engage people in order to satisfy their own goals and motivations, but also to benefit the other person.

Fong *et. al.* (2003:145) proposed the term **socially situated robots** – these are robots that are surrounded by a social environment, which they perceive and react to. Socially situated robots are able to distinguish between other social agents and various objects in the environment.

Socially intelligent – robots that show aspects of human-style social intelligence, based on possibly deep models of human cognition and social competence (Tzafestas 2015: 111).

2.2 Issues of sociable robots

What is a sociable robot has already been outlined in the chapter above, however it is a real challenge to design a robot that people would accept as a part of society. There are several main design and also ethical issues when it comes to building a sociable robot.

2.2.1 Design issues of sociable robots

Breazeal (2002: 235-241) named several design issues – the physical body, personality, human-like communication, personal recognition, empathy and autobiographic memory.

The physical body – robustness and durability of its body is important with all kinds of robots and the sociable ones are not an exception. It has to withstand daily existence in a human society and be able to stay functional. Its body needs to be able to protect the power source, actuator, sensors, cameras and all kinds of things that allow the robot to *live*. Nevertheless, with the technology currently available, I think that this is one of the smaller issues of designing a sociable robot.

There is also a question of appearance. There are many different designs of robots in movies and novels. Some are barely recognizable from humans and some look like a talking trash cans. A human-like robot could threaten people's identity, but on the other hand people may not be able to relate to a not "human-like talking thing", which is a crucial factor with sociable robots.

Personality – a sociable robot needs to have a rich and endearing personality and its actions and social cues have to be believable. This is one of the most essential attributes for a sociable robot. People would be more willing to interact and establish a relationship, if the robot had a rich and compelling personality. The tendency to anthropomorphise can be seen in a lot of today's toys (dolls, pet-like toys, children computers etc.)

Human-like communication – a sociable robot must be able to communicate at a high- level dialogue. The robot should be proactive and human needs to feel like they participate equally in a conversation. Social cues such as facial expressions, gestures and general emotions are really important.

Personal recognition – all people are different and have distinct personalities and a sociable robot must be able to distinguish people it already knows from the new ones. It needs to take into consideration past experiences with them and act accordingly. Various facial recognition, speaker identification devices or retinal and fingerprint scanners can help with this issue. It is also essential for them to understand individuals in social terms, be able to act and sway the interaction according to people's intents, beliefs and wishes.

Empathy – empathy is used to understand what others are feeling and is one of the pillars of social interaction. It is an essential trait, which a sociable robot must have.

Autobiographic memory – ability to reflect upon its past experiences and itself is something humans develop during the lifetime and through interaction with other people. A sociable robot must be able to learn and adapt continuously to new experiences, because it is impossible to pre-program it with everything it will need to know, since the human society is too complex and random.

2.2.2 Ethical issues of sociable robots

There are not only design issues, but also the ethical ones. As previously mentioned, sociable robots would be a big help in taking care of mentally ill people, elderly or even children. However, people get easily attached to things they own (cars, phones, toys etc.) and with sociable robots it would be no different, especially with the groups mentioned above. Tzafestas (2015: 119-120) mentions several – attachment, deception, awareness, robot authority, privacy, autonomy, human-human relation and justice and responsibility.

Attachment – a problem can arise here when people get emotionally attached to a sociable robot. A malfunction or a complete destruction of a robot can have the same impact as a death of a close person, however, it should not be the same. This could be a big problem especially with mentally ill people and children, because they can personify a robot and feel like it is a human, whereas a healthy person is less likely to do that.

Deception – a robot may be capable of looking like a doctor, teacher, nurse or a coach and it might be perceived as one by society and thus giving the impression that it can be as helpful as a human (but it cannot currently), which may be harmful.

Privacy – a robot may not be able to properly secure private information of people it interacts with, which could lead to a huge breach of privacy.

Human-human relation – if robots were to replace humans in professions, which require human interaction like doctors or therapists, it would lead to a reduction of a human-human contact. Mental state of people, who are fragile or suffer from some illness, and these interactions (therapist sessions) drive them, could significantly worsen, unless the technology is so refined that it could mimic humans perfectly.

Justice and responsibility – this is issue addresses the question of “who is responsible for the robot’s actions?”. If it malfunctions and happens to harm anyone, who is the one to blame? The designer, engineer, manufacturer or it even might be the owners fault.

There are a lot of issues and obstacles in the creation of autonomous sociable robots. With technology improving every day, the design issues are not as much of an obstacle as it might seem. The main problem here are the ethical and legal issues with this kind of robot. Chapter 2.4 deals with these problems in more detail.

2.3 Human-Robot Interaction

This chapter briefly introduces Human-Robot Interaction, which is a field of study that deals with interaction between a human and a robot.

Human-Robot Interaction (HRI) is a field of study dedicated to understanding, designing and evaluating robotic systems for use by or with humans. It is a relatively young discipline with its first conference originating in 1992 in Japan and continuing annually until today. This field tries to understand and shape the interactions between one or more humans and one or more robots. Interaction with people is the core of HRI and it can be divided into three directions or approaches, which are as follows – robot-centred HRI, human-centred HRI and robot cognition-centred HRI. (Dautenhahn 2007: 679-704)

Robot-centred HRI – this research branch’s primary concern is to develop technology for robots, which would enable them to feel emotions and help them interact with the social environment. This branch deals with the AI part of a sociable robot.

Human-centred HRI – this research branch on the other hand is primarily concerned with how people react to robots. What are they most suitable for, their appearance, behaviour. This branch deals with the technological part of a sociable robot.

Robot cognition-centred HRI – this research branch also deals with the AI, but more specifically – what is needed in a particular application domain.

2.4 European civil law rules in robotics

On February 16, 2017, the European Parliament adopted a formal resolution on civil law rules in robotics. The author of this study is Nathalie Nevejans and it was supervised and published by the Policy Department for "Citizens' Rights and Constitutional Affairs" in 2016. It addresses issues that the Parliament thinks need addressing, because of the advances made in robotics and artificial intelligence. The Parliament calls for the adoption of rules throughout the European Union to cover the legal and ethical ramification of this advancement in technology.

The resolution describes several legal and ethical issues described in the previous chapters, so that when autonomous sociable robots become a reality, the European Union will be able to seamlessly and successfully handle that situation.

2.4.1 Robots as liable legal persons

A new category of individual is proposed to be established, specifically for robots – electronic persons. The most sophisticated autonomous robots that make smart autonomous decisions could have the status of an electronic person with all the specific rights and obligations. [33]

However, when legal personality is assigned, we tend to assimilate it to humankind, to conscious beings, capable of suffering and feeling (like animals for example) and robots are not able to suffer or feel pain. Legal personality would also make robots liable for their actions, which would be really difficult in the court of law for example. There should always be someone responsible for a machine, even if it is smart and autonomous. Moreover, robots are made to make life easier and they should always serve humans and not the other way. [33]

2.4.2 Liability for damages caused by an autonomous robot

It is a really tricky question to decide who should be responsible for the actions of an autonomous robot, particularly if the robot is able to learn new things by itself. And with the legal personality of robots, it becomes even more difficult. However, a robot will always be something that humans design and construct and a physical person should be the one responsible for actions of a robot.

There are several options when deciding the responsibility for robot's action:

- **Software error** – when a robot is sold or produced with an open source software, which allows other people to manipulate with it, the person liable should be the one, who programmed it.
- **Design or production issue** – if a malfunction can be traced back to a design or a production, the person liable should be the designer or a producer.
- **User error** – if a robot causes any damage when it is still learning or it is not used properly, the person liable should be its owner or user for not using it properly. [33]

2.4.3 Roboethics

The machine ethics or the roboethics is still in a theoretical state, since even the smartest autonomous robots are incapable of taking moral decisions. However, even in this early stage it is essential that the ethics rules are primarily aimed at the protection of humans. [33]

Protecting humans from harm caused by robots – the first rule of roboethics and one of the most important ones is to protect humans from harm caused by robots. This rule is even the first law in Asimov's Laws of Robotics. [33]

Respecting of refusal of care by a robot – a person has the right to refuse to be cared for by a robot. This rule may apply for example when a robot is tasked with taking care of elderly or disabled people. If they do not feel comfortable in the presence of a robot, they have the right to decline its help. The other example is when a medical robot is to administer care, the patient needs to consent to it first. [33]

Protecting human liberty in the face of robots – an autonomous robot needs to be able to understand when it restricts people's liberty. It may try to protect a person, but if the person does not want to be or does not need to be protected it may lead to restriction of freedom and in Europe, human liberty is protected by law.

Example of this can be for example: detaining a runaway child or preventing an alcoholic from drinking alcohol. [33]

Protecting humanity against privacy breaches committed by a robot – autonomous robots will need a lot of sensors in order to function properly and with these sensors they will be able to gather a vast amount of information, which could be potentially misused. This rule should protect people from any privacy breaches committed by a robot, or rather by someone, who is capable of hacking or misusing a robot. [33]

Managing personal data processed by a robot – as I have already mentioned earlier, robots will gather large volumes of data with their sensors and with their ability to communicate, they will surely exchange data among themselves and with humans. This rule should forbid the robot from gathering information it is not supposed to gather as well as asking for consent when sharing personal information, health information etc. [33]

Protecting humanity against the risk of manipulation by robots – with the improving technology, robots can become so advanced, people can feel like robots have surpassed them, they might fear them or, on the other hand, be fascinated by them. Robots with human-like emotion can have a huge impact on some individuals. People can fall in love with a robot, however robot's emotions are fake, since it is a machine. This rule should prevent something like that from happening and ultimately helping people, who are susceptible to this kind of behaviour from seeing a robot as a real person. [33]

Avoiding the dissolution of social ties – this rule should help with ensuring that a robot's presence does not dissolve social ties entirely. It may not substitute a human being. In the future, assistance robots may become a norm for helping elder, disabled or sick people. They can help people at home even if they lose independence. Since a robot does everything for them, people would not need to maintain ties with other people, which would lead to a dissolution of social ties and this rule should prevent it from happening. [33]

Equal access to progress in robotics – this rule simply states to avoid creating a robotics divide. They should be available for everyone equally (education, healthcare, military etc.) The divide could happen primarily, because of the cost of robots. [33]

Restricting human access to enhancement technologies – people have always wanted to overcome their physical abilities and with robotic enhancements it could be achieved. It can be taken even further as to fuse a human with a machine. This rule strictly forbids this kind of enhancement. Nowadays, people use robotic prostheses to restore human function (prosthetic arm, leg etc.). These enhancements do not fall into the forbidden category. [33]

If these rules can be adopted and followed throughout European Union; and hopefully even the rest of the world, autonomous sociable robots can become the next huge milestone in the robotics industry.

PRACTICAL PART

3 Questionnaire

This chapter deals with a practical part of my bachelor's thesis. I have created a questionnaire with 14 questions and 5 answers to each question on a scale of 1 to 5 (1- strongly agree, 5 – strongly disagree). I have distributed the questionnaire among people in May 2017, it took about 2 weeks to gather all responses. The questionnaire was distributed electronically through social media and email. I have contacted around 200 people and 114 send the answer back. All respondents are from the Czech Republic.

The goal of this questionnaire was to gather information about the stance of people on autonomous sociable robots in society; attitudes towards them, their appearance and who should be responsible for them.

I have divided the questionnaire into 4 parts: respondents' personal data (2 questions), attitudes towards autonomous sociable robots (6 questions), visual appearance (3 questions) and responsibility for them (3 questions).

The list of questions:

I. Respondents' personal data

1. What is your gender?
2. How old are you?

II. Attitudes toward autonomous sociable robots

3. Do you like the idea of autonomous sociable robots coexisting with humans in society?
4. Do you think autonomous sociable robots should be considered a full-fledged members of society?
5. Do you think autonomous sociable robots should be used just as helpers (at home, at constructions, dangerous jobs etc.)?
6. In jobs, where there is a lot of human interaction needed; would you mind if an autonomous sociable robot was for example - a doctor, a therapist or a teacher?
7. Would you trust an autonomous sociable robot with your personal

information?

8. Would you say it would be fine to date an autonomous sociable robot?

III. Visual appearance

9. Do you think autonomous sociable robots should have human-like appearance?
10. Do you think autonomous sociable robots should have robot-like appearance?
11. Should they have kill-switches present somewhere on their body that would turn them off in case they got out of control?

IV. Responsibility for autonomous sociable robots

12. Should the government be responsible for them?
13. Should the manufacturer be responsible for them?
14. Should they be responsible for themselves?

3.1 Respondents' personal data

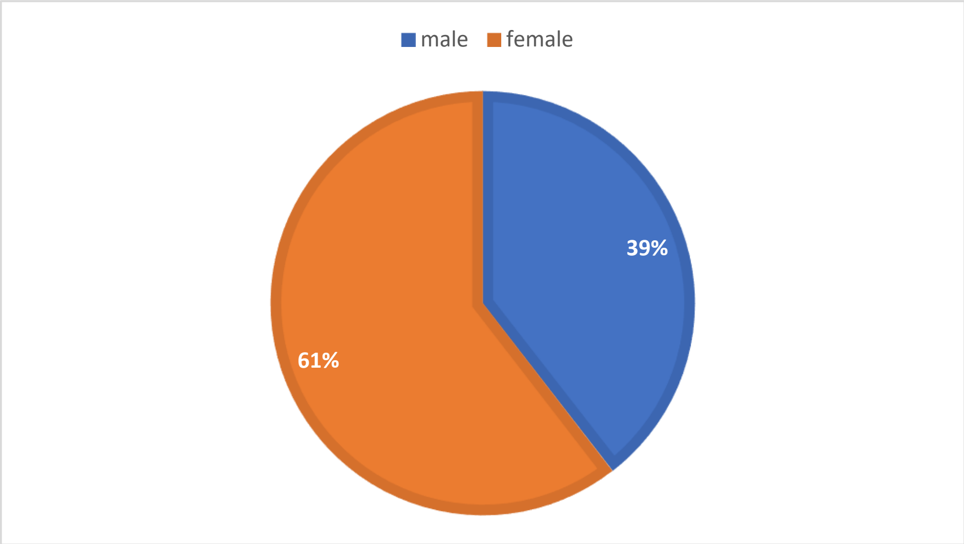
The questionnaire was completed by 114 respondents in total. Out of these respondents, 69 were women and 45 were men. The gender and age division is shown in tables and graphs below.

Question 1: **What is your gender?**

Responses to this question are shown in the table 1 and graph 1.

Table 1 - Gender of respondents

Gender	**n**	**%**
Male	45	39
Female	69	61
Total	**114**	**100**



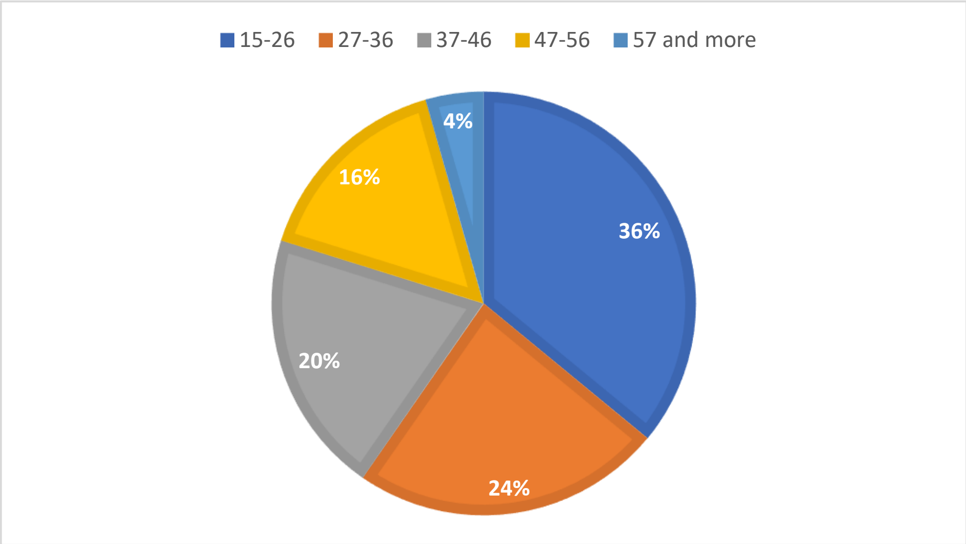
Graph 1 – Gender of respondents

Question 2: **How old are you?**

Responses to this question are shown in the table 2 and graph 2.

Table 2 - Age of respondents

Age	Total		Of that men		Of than women	
	n	**%**	**n**	**%**	**n**	**%**
15-26	41	36	11	10	30	26
27-36	27	24	15	13	12	11
37-46	23	20	11	10	12	11
47-56	18	16	6	5	12	11
57+	5	4	2	1	3	2
Total	**114**	**100**	**45**	**39**	**69**	**61**



Graph 2 – Age of respondents

3.2 Attitudes towards autonomous sociable robots

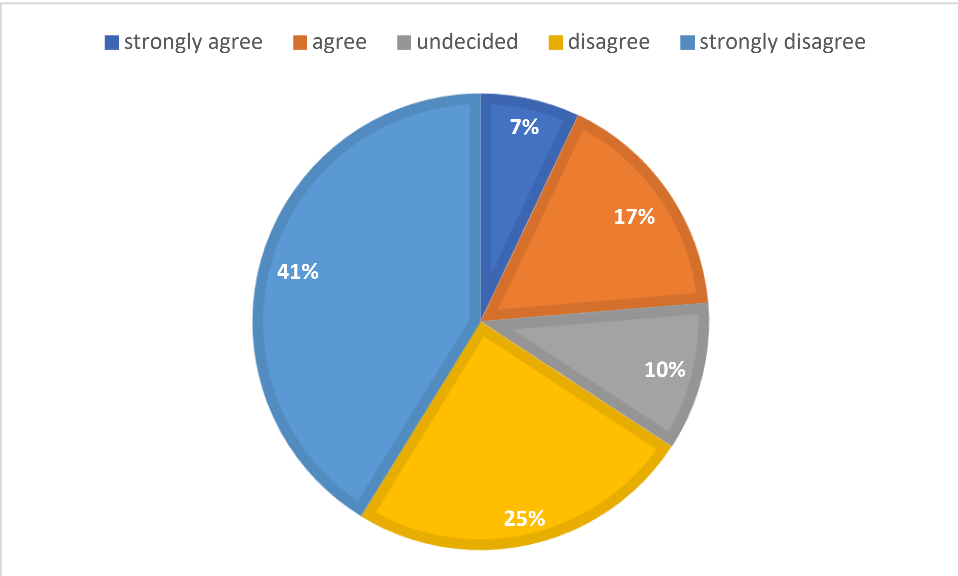
This part of the questionnaire had 6 questions aimed at the attitudes towards autonomous sociable robots.

Question 3: **Do you like the idea of autonomous sociable robots coexisting with humans in society?**

Responses to this question are shown in the table 3 and graph 3.

Table 3 – Autonomous sociable robots coexisting with humans in society

	total	
	n	**%**
Strongly agree	8	7
Agree	19	17
Undecided	12	10
Disagree	28	25
Strongly disagree	47	41
Total	**114**	**100**



Graph 3 – Autonomous sociable robots coexisting with humans in society

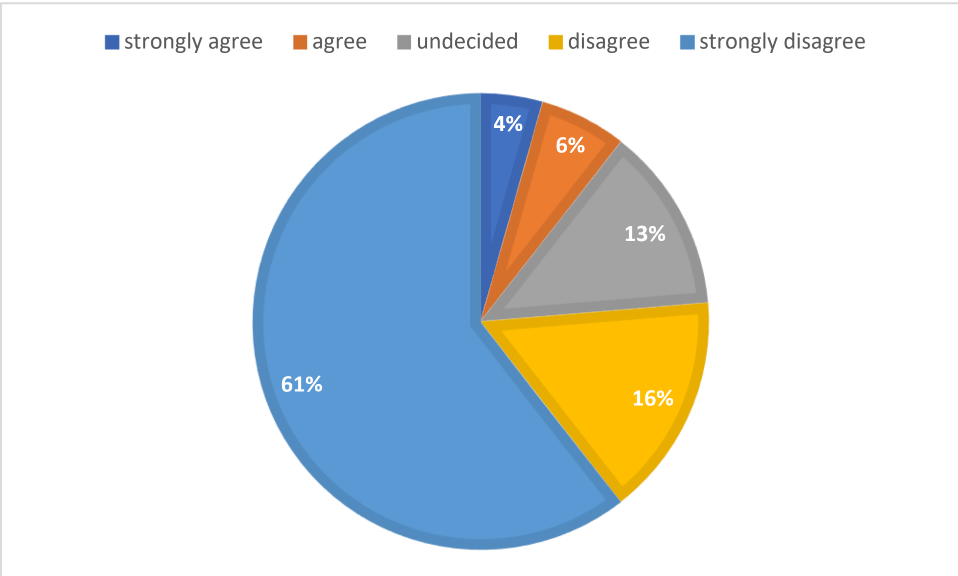
27 respondents (24%) agree with the idea of robots coexisting with humans in society, 12 respondents (10%) are undecided, whether they agree or not and a majority of the respondents – 75 (66%) do not agree with this idea.

Question 4: **Do you think autonomous sociable robots should be a full-fledged members of society?**

Responses to this question are shown in the table 4 and graph 4.

Table 4 – Autonomous sociable robots as full-fledged members of society

	total	
	n	**%**
Strongly agree	5	4
Agree	7	6
Undecided	15	13
Disagree	18	16
Strongly Disagree	69	61
Total	**114**	**100**



Graph 4 – Autonomous sociable robots as full-fledged members of society

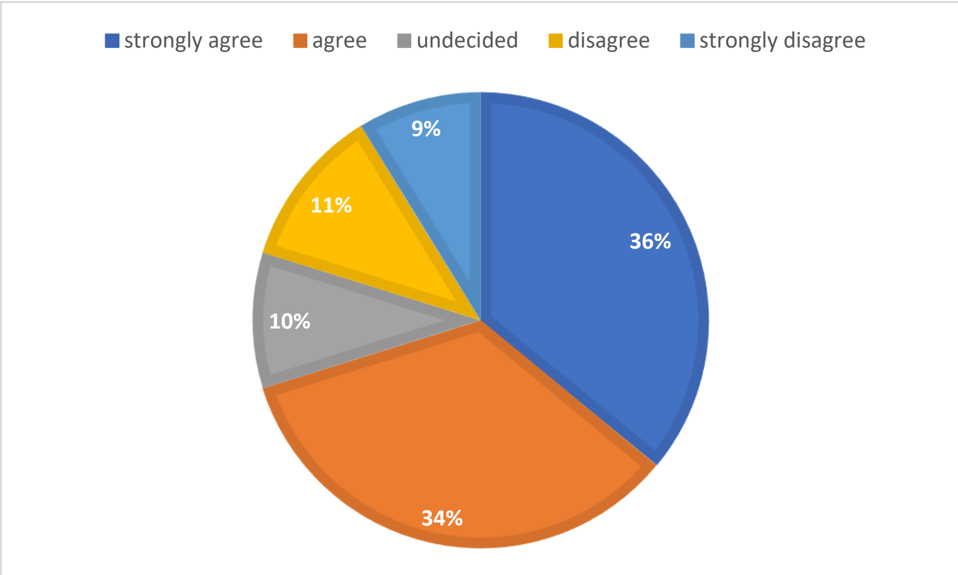
12 respondents (10%) think that autonomous sociable robots should be considered a full-fledged members of society, 15 respondents (13%) are undecided and again a majority of respondents - 87 (77%) do not think they should be a full-fledged members of society.

Question 5: **Do you think autonomous sociable robots should be used just as helpers (at home, at constructions, dangerous jobs etc.)?**

Responses to this question are shown in the table 5 and graph 5.

Table 5 – Autonomous sociable robots as helpers

	total	
	n	**%**
Strongly agree	41	36
Agree	39	34
Undecided	11	10
Disagree	13	11
Strongly disagree	10	9
Total	**114**	**100**



Graph 5 – autonomous sociable robots as helpers

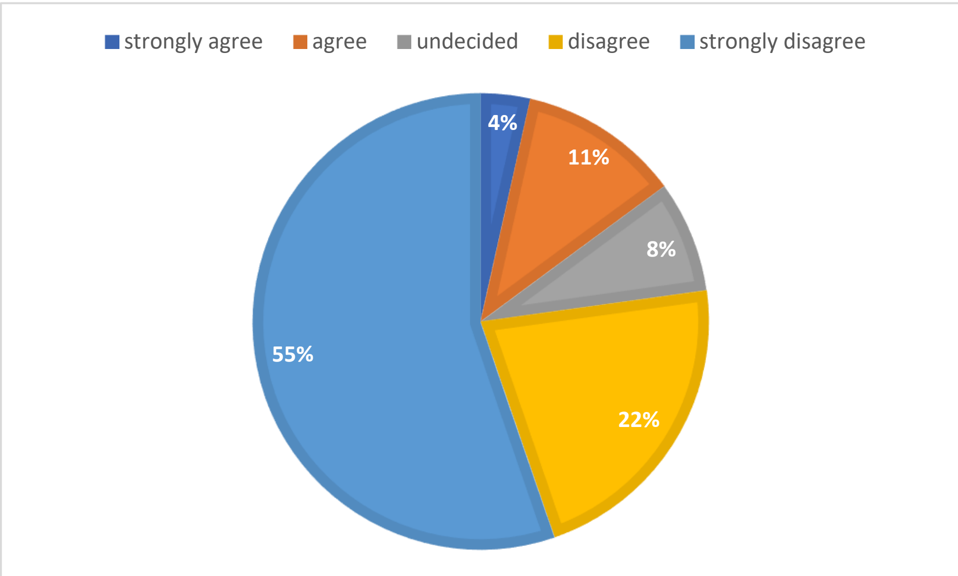
80 respondents (70%) think autonomous sociable robots should be used just as helpers, 11 respondents (10%) are undecided and 23 respondents (20%) disagree with them being just helpers.

Question 6: **In jobs, where there is a lot of human interaction needed; do you think it would be appropriate, if an autonomous sociable robot was for example - a doctor, a therapist or a teacher?**

Responses to this question are shown in the table 6 and graph 6.

Table 6 – Autonomous sociable robots as teachers, therapists, doctors

	total	
	n	**%**
Strongly agree	4	4
Agree	13	11
Undecided	9	8
Disagree	25	22
Strongly disagree	63	55
Total	**114**	**100**



Graph 6 – Autonomous sociable robots as teachers, therapists, doctors

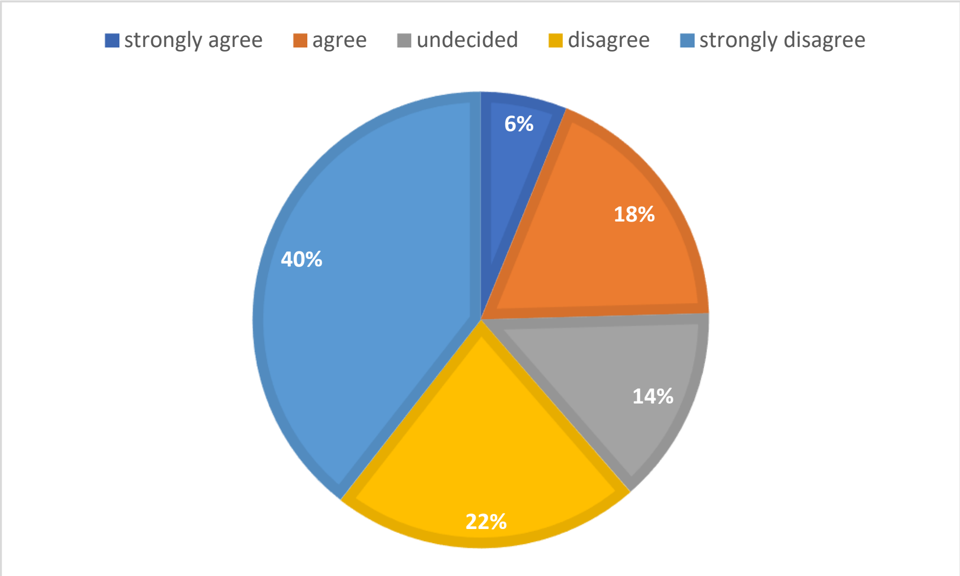
17 respondents (15%) think it is appropriate to have an autonomous sociable robot as a teacher, therapist, doctor etc., 9 respondents (8%) are undecided and a vast majority - 88 respondents (77%) do not think it is appropriate.

Question 7: **Would you trust an autonomous sociable robot with your personal information?**

Responses to this question are shown in the table 7 and graph 7.

Table 7 - Trusting an autonomous sociable robot with personal information

	total	
	n	**%**
Strongly agree	7	6
Agree	21	18
Undecided	16	14
Disagree	25	22
Strongly disagree	45	40
Total	**114**	**100**



Graph 7 – Trusting an autonomous sociable robot with personal information

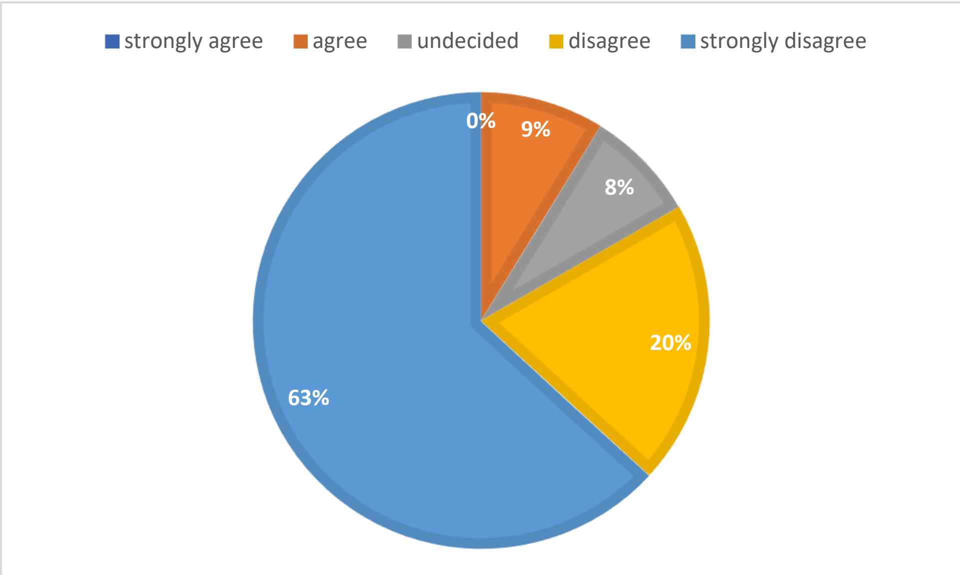
28 respondents (24%) would trust an autonomous sociable robot with their personal information, 16 respondents (14%) are undecided and 70 respondents (62%) would not trust them with their personal information.

Question 8: **Would you say it would be fine to date an autonomous sociable robot?**

Responses to this question are shown in the table 8 and graph 8.

Table 8 - Dating an autonomous sociable robot

	total	
	n	**%**
Strongly agree	0	0
Agree	10	9
Undecided	9	8
Disagree	23	20
Strongly disagree	72	63
Total	**114**	**100**



Graph 8 – Dating an autonomous sociable robot

10 respondents (9%) think it would be fine to date an autonomous sociable robot, 9 respondents (8%) are undecided and a vast majority - 95 respondents (83%) do not think it would be appropriate to date them.

3.3 Visual appearance

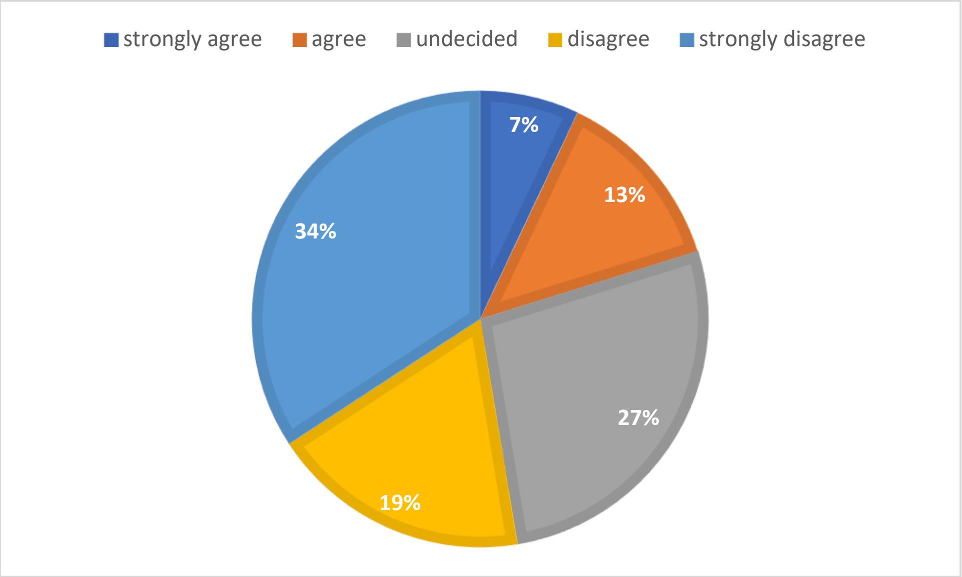
This part of the questionnaire had 3 questions aimed at the visual appearance of autonomous sociable robots.

Question 9: **Do you think autonomous sociable robots should have human-like appearance?**

Responses to this question are shown in the table 9 and graph 9.

Table 9 - Human-like appearance of autonomous sociable robots

	total	
	n	**%**
Strongly agree	8	7
Agree	15	13
Undecided	31	27
Disagree	21	19
Strongly disagree	39	34
Total	**114**	**100**



Graph 9 – Human-like appearance of autonomous sociable robots

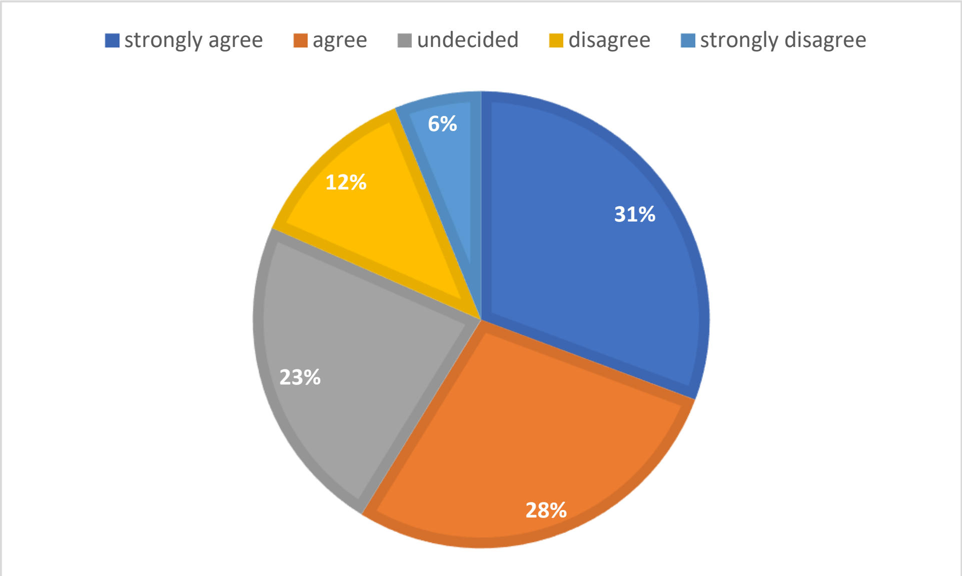
23 respondents (20%) would like for autonomous sociable robots to have human-like appearance, 31 respondents (27%) are not decided and 60 respondents (53%) do not want them to have human-like appearance.

Question 10: **Do you think autonomous sociable robots should have robot-like appearance?**

Responses to this question are shown in the table 10 and graph 10.

Table 10 - Robot-like appearance of autonomous sociable robots

	total	
	n	**%**
Strongly agree	35	31
Agree	32	28
Undecided	26	23
Disagree	14	12
Strongly disagree	7	6
Total	**114**	**100**



Graph 10 – Robot-like appearance of autonomous sociable robots

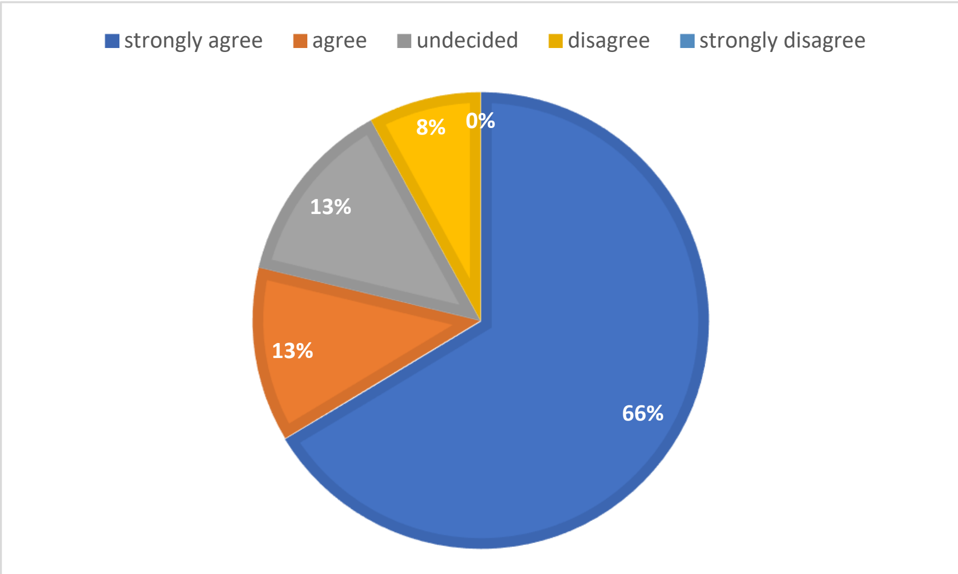
67 respondents (59%) would like for autonomous sociable robots to have robot-like appearance, 26 respondents (23%) are undecided and 21 respondents (18%) do not want them to look like robots.

Question 11: **Should they have kill-switches present somewhere on their body that would turn them off in case they got out of control?**

Responses to this question are shown in the table 11 and graph 11.

Table 11 – Kill-switches for autonomous sociable robots

	total	
	n	**%**
Strongly agree	75	66
Agree	14	13
Undecided	15	13
Disagree	9	8
Strongly disagree	0	0
Total	**114**	**100**



Graph 11 – Kill-switches for autonomous sociable robots

89 respondents (79%) think autonomous sociable robots should have a kill-switch on their body, 15 respondents (13%) are not decided and 9 respondents (8%) do not think they should have a kill-switch.

3.4 Responsibility for autonomous sociable robots

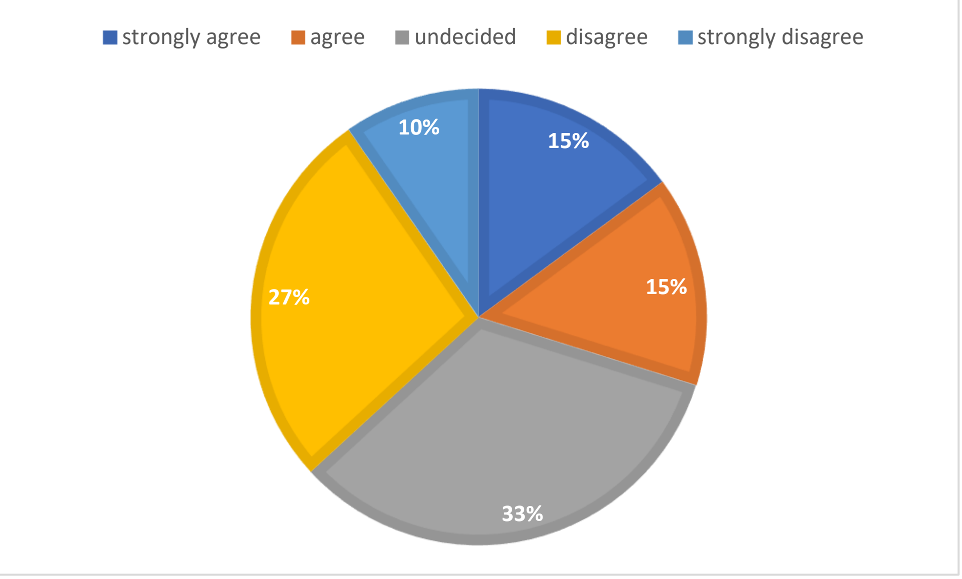
This part of the questionnaire had 3 questions aimed at the responsibility for autonomous sociable robots in case of a malfunction.

Question 12: **Should the government be responsible for them?**

Responses to this question are shown in the table 12 and graph 12.

Table 12 – Autonomous sociable robots as responsibility of the government

	total	
	n	**%**
Strongly agree	17	15
Agree	17	15
Undecided	38	33
Disagree	31	27
Strongly disagree	11	10
Total	**114**	**100**



Graph 12 – Autonomous sociable robots as responsibility of the government

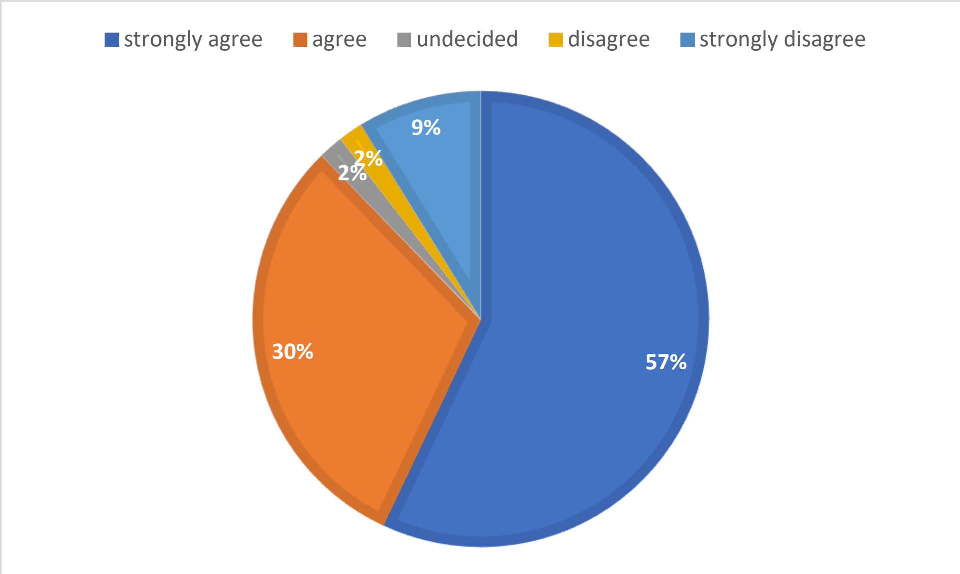
34 respondents (30%) think the government should be responsible for autonomous sociable robots in case of a malfunction, 38 respondents (33%) are not decided and 42 respondents (37%) do not think the government should be responsible for them.

Question 13: **Should the manufacturer be responsible for them?**

Responses to this question are shown in the table 13 and graph 13.

Table 13 – Autonomous sociable robots as responsibility of a manufacturer

	total	
	n	**%**
Strongly agree	65	57
agree	35	30
Undecided	2	2
Disagree	2	2
Strongly disagree	10	9
Total	**114**	**100**



Graph 13 – Autonomous sociable robots as responsibility of a manufacturer

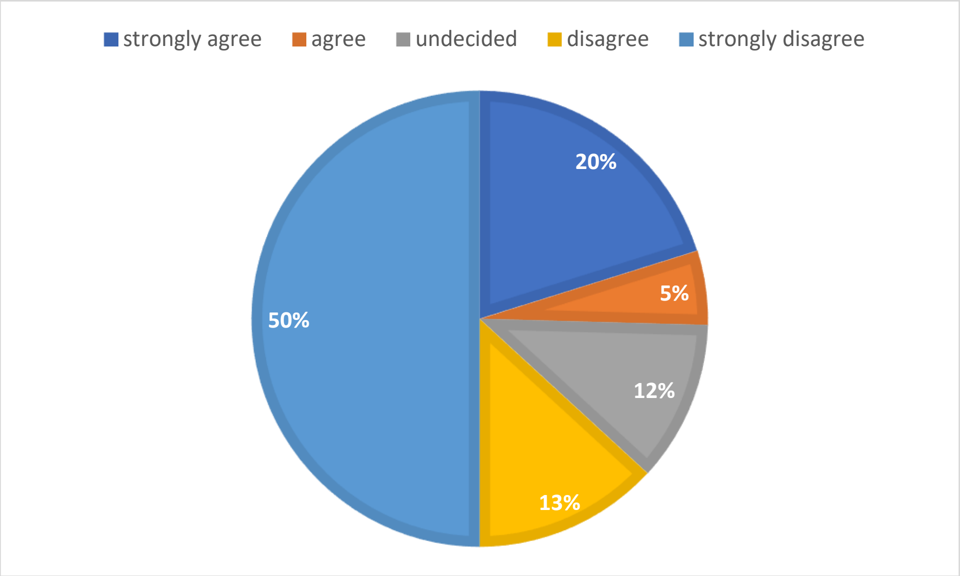
100 respondents (87%) think a manufacturer of autonomous sociable robots should be responsible for them in case of a malfunction, 2 respondents (2%) are undecided and 12 respondents (11%) do not think a manufacturer should be the one responsible.

Question 14: **Should they be responsible for themselves?**

Responses to this question are shown in the table 14 and graph 14.

Table 14 – Autonomous sociable robots responsible for themselves

	total	
	n	**%**
Strongly agree	23	20
Agree	6	5
Undecided	13	12
Disagree	15	13
Strongly disagree	57	50
Total	**114**	**100**



Graph 14 – Autonomous sociable robots responsible for themselves

29 respondents (25%) think autonomous sociable robots should be responsible for themselves, 13 respondents (12%) are not decided and 72 respondents (63%) do not think they should be responsible for themselves.

The results as a whole are no that surprising, most of the respondents do not want to live in a society with autonomous sociable robots and they would not want them to be full-fledged members of society. Robot doctors, teachers or therapists are out of question, but the respondents would not mind them being helpers at constructions or at home. Most of the respondents would also not trust an autonomous sociable robot with personal information. As for dating a robot, majority of the respondents think it would be inappropriate.

In the questions about appearance a lot of the respondents could not decide, whether they want them to look like a human or a robot, however about a half of the respondents would want them to have a robot-like appearance. A vast majority of respondents also think that autonomous sociable robots should have kill-switches.

As for the responsibility in case of a malfunction, most of the respondents think a manufacturer should be the one responsible for them.

4 Conclusion

This bachelor's thesis focuses on robotics, which is an interdisciplinary branch of engineering and science and is one of the most prominent and potentially world changing fields of research. It was really interesting to get to know more about a topic I knew only from books and movies, but was always fascinated by.

The theoretical part of this bachelor's thesis dealt with the history of robotics and introduced the term robot. It described what aspects should a robot have. Then it focused on the history of robotics from the fascinating *Antikythera Mechanism* invented by the ancient Greeks, famous automata by Leonardo da Vinci, Vaucanson's *Digesting Duck*, revolutionary robotic arm *Unimate,* up to NASA's space rovers, humanoid robots of Waseda University, Honda's helper ASIMO and remarkable human-like robots created by Hanson Robotics.

The next part of this bachelor's thesis focused more in detail on sociable robots. It dealt with the aspects of sociable robots and social skills needed for various application domains. It outlined various definitions of sociable robots from Cynthia Breazeal and other authors. The thesis then focused on design and ethical issues of sociable robots and briefly introduced a field of study dedicated to interaction between a human and a robot – Human-Robot Interaction. It also dealt with European Civil Law rules in Robotics, which is a newly adopted resolution on legal and ethical rules in robotics. These rules should be adopted throughout the European Union.

The practical part of my bachelor's thesis dealt with the results of a questionnaire survey. The goal of this questionnaire was to acquire information about people's stance towards autonomous sociable robots in society. As the results suggest, respondents to the questionnaire do not want to live with robots, however intelligent they may be, in society. Although, they would not mind having them as helpers. Respondents would also like to have them under control with kill-switches and would want the manufacturer to be responsible for them.

Although it is not wanted, the robotic revolution is in full swing and it cannot be stopped. It is only a matter of time when robots completely replace people who work manually and we can only wait and see in which areas of human life will be robots deployed in the future.

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